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pragmatic test, nor the whole of it. It leaves out the reference to the *consequences* of acting on a belief, and the logical reaction of *success* or *failure* on the original belief, and consequently fails to connect the "true" with "satisfaction" and with the "good." Neither does it lay down the logical canon that *all truth-claims* must be tested. In short, it covers only a small part of the ground over which the pragmatic controversy has since extended.

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A NOTE ON THE NEEDS AND USES OF ENERGY MEASUREMENTS FOR WORK IN PSYCHOLOGICAL OPTICS

A BRIEF discussion of this subject was given by us five years ago in an article, entitled "A Note on the Determination of the Retina's Sensitivity to Colored Light in Terms of Radiometric Units."[1] Since that time some dispute has arisen with regard to the comparative merits of the subjective and objective types of measurement of the stimulus light for work in psychological optics. Time alone can, of course, reveal the full range of needs and uses of the objective type of measurement. A few words in the way of general perspective, however, may not be out of place at this time.

Considered in its relation to the eye, two points of view may be recognized in the rating of lights. One of these is involved in their rating for the use of the eye as an organ of seeing. In such a rating it is obvious that the method should take into account all of the eye's peculiarities of response to the different wave-lengths of light. In the production of illuminating effects this is the work of photometry, which should be done by the eye or some instrument calibrated to give results in terms of the responses of the eye. Another and quite a different point of view, however, is involved in their rating for the purpose of investigating the eye's peculiarities or characteristics of response in every way in which it is capable of giving response. In such work it is obvious that the ultimate method of making the rating should be free from the peculiarities to be investigated, that is, should not be made by the eye itself. In general, in work of this kind, two needs arise. (1) A method of specification is required which will make possible an accurate and convenient reproduction of intensities from time to time and from laboratory to laboratory. The difficulty of doing this by photometry with lights differing widely as to wave-length, as do in most cases the stimuli employed in psychological optics, is too well known to need emphasiz-

ing here. Obviously what is needed for certitude in this work, is a measuring instrument which can be calibrated directly against the standard of radiation, or black body, and which is non-selective in its response to wave-length—not an instrument like the eye, the selenium cell, the photo-electric cell, or the photographic plate, the responses of which are not only selective to wave-length, but vary in their amounts of selectiveness with change of intensity of light, differ greatly in both of these regards (especially the eye) from instrument to instrument or from sense organ to sense organ, and can not be calibrated against the total of radiation of a black body.

The insistence on a subjective method of rating for standardizing purposes, when the objective method is available, is not only difficult to understand, but is entirely contradictory to current practise in other sense fields. No one would think, for example, of specifying, for the purpose of securing reproducibility, the weights used in an investigation of skin sensitivities in terms of the skin's own responses when the means of making the physical measurement is at hand; yet there should be more chance of successfully establishing from laboratory to laboratory a system of calibration of skin measurements in terms of some common standard than there is of accomplishing the analogous task in case of light. It is scarcely conceivable that the most ardent advocate of subjective ratings in case of light would recommend the substitution of the subjective for the objective method for work on the skin for the simple reason that it would be so undesirable as not to be tolerated unless, for want of an objective method, it was rendered absolutely necessary. With the objective method available from the beginning, the possibility of using the subjective method has not even been raised in work on the skin. And indeed the subjective method has been used in rating light intensities only because (*a*) for more than a hundred years no other method was available, and (*b*) it was desirable to rate lights for use in seeing by a method which gave results corresponding to the eye's powers of response. The former of these reasons for its use has now disappeared. Only the latter, with a few laboratory exceptions, remains and marks off for the subjective method of rating a separate and special field which is clearly recognized as such by physicists and the engineers dealing with the problem of lighting.

As a brief, however, for the continuation of the use of the eye for the measurement of its own stimuli, although such measurements would not be subjective, it may be claimed that in time it will be possible to calibrate the eye by means of the non-selective radiometers so that it can be used to measure the visible energies directly. For example, just as it is possible to measure a linear dimension with

a meter rod and to convert the results into terms of the English system, and *vice versa;* so it may be possible to measure the different wave-lengths of light by the eye and convert the results obtained into energy values. The difficulties in the way of this, as we have already pointed out, consist in differences in the sensitivity of different eyes for a given wave-length; the selectiveness of the eye's response to wave-length and to intensity and its variations in both of these regards from observer to observer; the lack of a fixed scale from observation to observation, even in the case of a single observer, *etc.* In short, to complete the analogy suggested above, it would be an exceedingly difficult task to convert measurements from the metric into the English system and *vice versa* if very few of the measuring rods employed represented the same amounts of linear space; if in case of a given rod the dimensions of some objects were underestimated and others overestimated and the magnitude of this underestimation and overestimation varied with the dimensions of the object measured by amounts as yet undetermined, *etc.,* as happens in case of the eye's evaluations of the wave-lengths of the visible spectrum. Obviously if the eye's ratings are to be converted into energy values, this conversion can come only after a very great deal of investigation and calibration against radiation standards by means, for example, of the non-selective radiometers, which but constitutes one of the subdivisions of what we have included under the second of the needs we are giving for energy measurements in the study of the responses of the eye. However, to represent the calibration as now completed and available for use instead of scarcely begun, as is being done in some quarters, is chimerical and visionary to a degree which we can consider compatible only with an inadequate knowledge and understanding of all that is involved in the problem.

(2) The second and perhaps more fundamental need for energy measurements for work on the eye is, as stated in the general heading, for a method of rating the stimulus which will make possible a quantitative comparison of the eye's power of response to its stimuli in every way in which it is capable of giving a response; for we can know the kind and amount of its selectiveness of reaction to the different wave-lengths of light only when they are compared with those of an instrument as a standard which shows equal power or capacity of response to all wave-lengths. Only with such an instrument, or rather with such an evaluation of the stimuli as a common or invariable standard to which to refer the eye's evaluations or responses, can the work of comparing its powers or peculiarities of response to its stimuli be put on a basis that can be called quantitative for a single eye or from eye to eye. To this it may be demurred, however, that in some problems it is required as one of the

features of the investigation that the stimuli have equal power to arouse the eye's response or sustain some subjective relation to each other. This need we have always freely recognized both in our work and in our recommendations.[2] It in no way conflicts with, however, or supplants the more fundamental one already given, but is rather supplementary to it in certain types of investigation; for even in the cases where the subjective relation is demanded to fulfil the requirements of the investigation there is still great need for the ultimate purposes of the science that the physical amounts of light required to produce this subjective relation for the given observer be determined and specified. Again to use the analogy of work on skin sensation, it would be a careless investigator indeed who would fail to specify, if it were possible to do so, the physical measure of the weights he used to give equal pressure responses, for example. In short, it seems a paradox that one should even feel the need to make a special pleading for the introduction of objective measurements into the work of psychological optics when it is the current practise to use objective ratings of the stimulus in every other field of psychological investigation in which it is possible to do so, the intensity ratings in vision and audition alone being the conspicuous outstanding exceptions and these being so only because adequate methods for making such ratings have been slow in coming.

As examples of needs for regulating the stimuli to give certain subjective relations we may quote here the following cases that we have already formally recognized. In a recent investigation of the comparative lags of the achromatic response to wave-length made in our laboratory, the stimuli employed were made photometrically equal and the amounts of light used to give these equal responses were measured radiometrically. The photometric equalizations were made because the data were wanted in an interpretation of the characteristic overestimations and underestimations found in the results of certain observers in photometry by the method of flicker as compared with their results by the equality of brightness method. In another case in a determination of whether stimuli which have the same power to arouse the achromatic response have also the same power to make the eye lose in its capacity to give this response as a result of prolonged stimulation, the stimuli were as a matter of course made subjectively equal as one of the essential conditions of the investigation; but again the amounts of light required to produce this subjective relation were determined radiometrically for the purpose of ultimate specification. Also in our

[2] See, for example, *American Journal of Psychology*, Vol. XXIII., pp. 329–331.

original note on energy measurements we recognized quite broadly the possible need of establishing subjective relations between the stimuli used. For example, in discussing methods of determining after-image and contrast sensitivity, we state: "It is conceivable that two points of view may be held with regard to what is meant by after-image and contrast sensitivity. (1) After-image and contrast sensitivity may express a relation between the amount of light required to arouse after-image and contrast sensations and the unit of light used. (2) It may express a relation between the amount of light required to arouse the after-image and contrast sensations and the amount required to arouse the positive sensation."[3] In the former case the after-image or contrast sensations are treated as one of the eye responses the selectiveness of which to wave-length is to be determined; in the latter a figure is sought which expresses the relation between the after-image and contrast and the positive sensitivities. On the same page and the one following we say: "Similarly, two views may be held with regard to the determination of the comparative rates of fatigue, and of the development-time of sensation. (1) Lights equalized in energy may be used. (2) The energy of the lights may be made proportional to the sensitivity of the eye to the different colors." Also in discussing the investigation of the peripheral limits of sensitivity, we state: "(*a*) The limits may be considered in relation to the comparative sensitivity of the retina to the different colors. (*b*) They may be considered in relation to existing color theories. In the first of these problems the limits should be obtained with stimuli equalized in energy. So obtained, the results will constitute merely another expression of the comparative sensitivity of the retina to the different colors." "The second problem is more complicated and will be made the subject of a separate paper." Indeed, as these citations abundantly show, we have never failed to recognize that the stimuli in certain types of investigation must be made to conform to some type of subjective relation, but these investigations constitute in immediate importance only a minor part of the work that is to be done in getting a thorough knowledge of the eye's characteristics of response; and even in these investigations there is as great need of an invariable standard of reference as there is in any field, psychological or otherwise, where the value of quantitative work or measurement is recognized.

Perhaps the general character of the discussion will not be deviated from too widely if we add in conclusion a word on the determination of retinal sensitivities which will indicate in a concrete case the type of treatment that should in our opinion be given

[3] *Op. cit.*, p. 329.

both to the response and to the stimulus, when possible, in quantitative work in psychological optics. If the sensitivity of the retina is to be measured in a way that is comparable with the measurement of the sensitivity of the physical recording instruments, two conditions must be fulfilled: (*a*) the amounts of response in terms of which the comparison is to be made must be numerically comparable; and (*b*) the amounts of stimulus used in arousing the response must also be numerically comparable or commensurable. The sensitivity of two galvanometers could not be compared, for example, were it not known that the divisions on the scale of each were either equal or commensurable; likewise the amounts of current used to produce the given deflections must be known in terms of the same or comparable units. With the introduction of the radiometric treatment of the stimulus the second of the above conditions is fulfilled, and for the first time in a way that can be considered quantitative to a degree that would be acceptable in rating the sensitivity of a physical instrument. With reference to the first condition we are confronted with a situation somewhat similar to that which obtains in heterochromatic photometry. That is, in general, five different quantities have been used or suggested in the work of measuring sensitivities (the liminal threshold, the just noticeable difference, the average error, equal amounts of response and equal sense differences), but only the last two of these conform to the requirement that is considered absolutely necessary in determining the sensitivity of a physical instrument, namely, that the amounts of response as well as the amounts of stimulus must be numerically comparable. Moreover, in the absence of sureness of principle in case of the other three, the empirical check of agreement in result with those that have the needed sureness of principle has never been offered; yet sensitivities are determined just as if this condition did not exist, comparisons are made and conclusions are drawn. In short it may not be out of place to call attention here to the looseness of thinking and practise that prevails more or less generally with regard to the work of determining physiological sensitivities as compared with the analogous physical determinations. For the sake of consistency it might well be urged either that this work be revised on the basis of the standards set for the physical instruments with all of the interchecking of methods that is needed, or that the term sensitivity with its definite quantitative connotation be abandoned in all cases in which this standard can not be lived up to.

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